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Perceptions of vulture supplementary feeding site managers and potential hidden risks to avian scavengers

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Abstract

Under the current African vulture crisis, supplementary feeding sites (SFS), which provide carrion resources, have become a popular conservation tool to address vulture declines. In South Africa, this practice is unregulated and the context in which SFS operate and their adherence to best management practices is currently unknown. In this study, we conducted a survey with SFS managers regarding the management of their SFS to evaluate potential conservation implications of different practices. Half of the SFS surveyed were associated with livestock farming. Overall, most managers (84%) perceived some benefit from running an SFS, largely attributed to cleaning services provided by vultures. Over half of the managers perceived no disadvantages from running SFS. We found a positive correlation between numbers of vultures seen at SFS and the amount of food provided there. Despite unintentional and intentional poisoning being identified by experts as the most critical threats to vultures in Southern Africa, only 47 and 24% of managers, respectively, listed these as potential threats to vultures, highlighting limited understanding of current vulture conservation issues. Most managers (85%) vetted carcasses for provisioning suitability based on whether they had been treated with veterinary drugs, but relatively few managers (10%) did the same for lead (Pb) contamination. Only 30% of managers considered threats to vultures when they decided on a location for their SFS. Overall, this study unveils that at many SFS, safety conditions are not met and vultures may be exposed to risks, such as the ingestion of toxic substances (e.g., Pb) or electrocution by energy infrastructure. To minimize unintended negative consequences from SFS, it will be essential to increase the interaction between SFS managers and conservation practitioners, to increase the flow of information on best management practices and enforce stringent and clear guidelines that minimize any risks to vultures.

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KEYWORDS

best management practices, contaminated carcasses, ecotoxicology, stakeholder perceptions, vulture crisis, vulture restaurant

1 | INTRODUCTION

Community and stakeholder engagement is often a prerequisite for the success of conservation initiatives (Hulme & Murphree, 1999; Kumasi, Obiri-Danso, & Ephraim, 2010). As a result, many conservation programs have shifted from top-down regulatory approaches to bottom-up voluntary initiatives that foster stewardship and the appreciation of ecosystems and their services (Santangeli, Arroyo, et al., 2016). In many cases, local communities rather than the government or organizations are responsible for the implementation of conservation initiatives, a situation which is easier to establish if there is some benefit to participating individuals (Naidoo et al., 2016). Community involvement in conservation initiatives has considerable potential (Nelson et al., 2010; Olsson & Folke, 2001), but these benefits can be tempered by the competence of community members and the extent to which best practices are followed. When best practices are poorly applied, such initiatives may have detrimental ecological effects (Blanco, Lemus, & García-Montijano, 2011). In such cases, detrimental effects on the target species or system may occur, while still providing short term benefits to participating community members, conceivably resulting in these practices being perpetuated.

Vulture supplementary feeding sites (SFS, also referred to as vulture restaurants) are a popular tool implemented under the assumption that they can help avert the dramatic declines of old-world vultures (Brink et al., 2020; Cortés-Avizanda et al., 2016). The popularity of SFS is likely because they conceptually present a win-win scenario for landowners and vultures. SFS provide a cost-effective carcass disposal method for landowners who would otherwise have to burn or bury their carcasses to ensure biosecurity on their farms. Alternatives often require expensive equipment, such as earth moving vehicles or industrial-scale incinerators, which also have operating costs along with transportation costs, compared to SFS that in many cases only require transport costs. Additionally, SFS may provide a tourism attraction that can help attract customers for landowners that offer hospitality services. Among the proposed benefits to vultures is a reduced poisoning risk, the main threat driving vulture declines. Although based on a sample of only six Oriental white-backed vultures, *Gyps bengalensis*, Gilbert, Watson, Ahmed, Asim, and Johnson (2007) found reduced diclofenac poisoning-related mortality rates in

response to SFS establishment, thereby providing some support for this tool in conservation. Other proposed positive effects include improved breeding success and survival (Botha et al., 2017; Margalida, Colomer, & Oro, 2014). These effects have, however, not been ubiquitously or conclusively demonstrated (Schabo et al., 2017), and in many cases, SFS establishment is based on assumptions rather than science (Oppel et al., 2016).

Worryingly, SFS may even result in unintended negative consequences. These may include changes in foraging patterns or habituation (Fluhr, Benhamou, Riotte-Lambert, & Duriez, 2017; Gilbert et al., 2007), negative health consequences and disease transmission (Blanco et al., 2011; Botha et al., 2017; Brink et al., 2020), decreasing productivity (Carrete, Donazar, & Margalida, 2006), and the monopolization of resources by certain age classes or species (Cortés-Avizanda, Jovani, Carrete, & Donazar, 2012; Duriez, Herman, & Sarrazin, 2012). SFS may also have cascading effects on nontarget species by increasing local predation pressure (Cortés-Avizanda, Carrete, Serrano, & Donazar, 2009). There are thus likely many benefits and disadvantages from SFS which should be considered before assuming a net gain (Cortés-Avizanda et al., 2016).

In South Africa, conservation organizations have long promoted the establishment of informal and privately run SFS (Anderson, Piper, & Swan, 2005; Mundy, Butchart, Ledger, & Piper, 1992). These are proposed as a cost-effective waste management solution that also supports endangered avian scavenger species, especially vultures. The use of SFS is now commonplace. A recent study (Brink et al., 2020) consolidated records of SFS in South Africa from various conservation organizations and surveyed their managers. This study verified 143 active SFS across the country that provide an estimated 3,301 t of food annually, equivalent to 83% of the food requirements of all vultures in the region. Additionally, many informal small SFS likely remain undocumented (Craig, Thomson, Girardello, & Santangeli, 2018; Pfeiffer, Venter, & Downs, 2015). In South Africa, landowners are free to dispose of unwanted animal carcasses by providing them to scavengers, and this practice is currently unregulated. It is likely therefore that this practice is commonplace for landowners in areas where vultures and other scavengers are present. SFS seem to be an ideal scenario, perfectly aligned with UN Sustainable Development Goal 15 “Life on Land” which aims to facilitate development while protecting biodiversity. However, for

SFS to deliver sustainability outcomes, as mentioned above, they should provide a net benefit for vultures and for people.

If SFS are not managed responsibly, these sites might not have the desired beneficial effect on vultures and other scavenger species. For example, the safety of carcasses provided at SFS is a concern. Lead (Pb) is toxic to animals, including vultures (Naidoo, Wolter, Espie, & Kotze, 2012; Pikula et al., 2013), and has been documented to accumulate in African vultures with the likely source of contact being lead shot contained within the carcasses of hunted animals (Garbett et al., 2018; van den Heever, Smit-Robinson, Naidoo, & McKechnie, 2019). This source of lead nearly drove the California condor, *Gymnogyps californianus*, to extinction in North America, and the use of lead ammunition within condor habitat has consequently been banned (Finkelstein et al., 2012). The ingestion of veterinary drugs can also have dramatic impacts on vulture populations, as shown by the catastrophic declines in Asian vulture populations due to the anti-inflammatory drug, diclofenac (Green et al., 2004; Shultz et al., 2004). The effect of many routinely used veterinary drugs on vultures, such as antibiotics, remain unassessed. Gómez-Ramírez et al. (2018) found that despite farmer assurances that carcasses provided at SFS in Southeastern Portugal were not treated with antibiotics, 29% of meat samples contained antibiotic residues. In South Africa, 68% of SFS managers were unaware that lead, and 28% were unaware that veterinary drugs, can have negative health consequences for vultures (Brink et al., 2020). Vultures may thus routinely be ingesting these substances at SFS. Besides the provisioning of contaminated food, other unsafe management practices would include placing SFS in close proximity to power lines or fences and bird unfriendly reservoirs, leading to potential collisions/electrocutions and drowning, respectively (Piper, 2004). Best management practices for SFS therefore aim to reduce vultures' exposure to the above mentioned threats (Birds of Prey Programme, 2007). This includes taking steps to ensure that food provisioned is free from contaminants and ensuring that SFS placement does not expose vultures to threats.

If conservation practitioners want to influence the management practices of private individuals using this unregulated conservation tool, then they need a good understanding of the perceptions, motivations, and knowledge base of the individuals engaging in this practice (Kareiva & Marvier, 2012). In this study we aim to fill this knowledge gap by (a) providing information on the land management context in which SFS function; (b) determining vulture visitation and how this may be affected by provisioning rates; (c) determining the level of awareness of SFS managers to the anthropogenic threats vulture face

and their knowledge of best practices as applied to SFS. This information will provide useful insights to inform future interactions between conservation managers and SFS managers. It will also serve as an urgent call to the conservation community to evaluate the application of this conservation tool. Although SFS have many potential conservation benefits, it also has the potential to negatively affect an entire and highly threatened guild, with potential cascading effects on the ecosystem.

2 | METHODS

Brink et al. (2020) recently collated, updated, and verified a national SFS database for South Africa. This database contains information from various organizations extensively involved in vulture research and conservation (FitzPatrick Institute of African Ornithology, VulPro, Ezemvelo KwaZulu-Natal Wildlife, and the Endangered Wildlife Trust). The data for this present study were simultaneously collected alongside that project. Thus, at the same time as confirming if the SFS was active (supplying at least one carcass per year), we surveyed the managers or affiliated personnel of these SFS. The survey was conducted by a single interviewer (C. W. B.) over the telephone or email, via an open-ended questionnaire (Data S1) between November 2017 and October 2018. Telephonic contact was always first attempted and email was only used if requested by the respondent or if telephonic contact could not be established. Although different survey methods may affect the results, these effects are not ubiquitous and usually small (Elliott et al., 2009; Rutherford et al., 2016). Self-administered questionnaires generally suffer more from nonresponse bias while interviewer facilitated methods suffer more from social desirability bias, which is more prominent if the subject matter is sensitive (De Leeuw, 2005). Mixed-mode strategies (e.g., telephonic interviews and self-administered email questionnaires) are consequently often used to compensate for the weaknesses of each individual mode (De Leeuw, 2005). Because our questionnaire did not contain any particularly sensitive questions, we assumed that reduction in nonresponse bias due to a mixed-mode approach would outweigh any potential differences in social desirability bias between the two techniques. Respondents were asked a range of questions pertaining to the context in which their SFS was operated, the carcasses they provided, their perceptions regarding the benefits and disadvantages of running a SFS, perceived trends in number of visiting vultures, knowledge on the current threats to vultures, and their awareness of best management practices. We also asked SFS managers to provide an indication of the average number of vultures

present during a feeding event (Question 22, Appendix S1). For the full list of questions, see Appendix S1.

Only SFS verified as active were included in our questionnaire study. As these were open-ended questionnaires, some responses were not relevant and were excluded from analyses. For example, when respondents were asked to list all the threats to vultures in South Africa that they knew about (Question 29, Appendix S1), only threats of anthropogenic origin and those mentioned in the Multi-Species Action Plan (MSAP) were considered relevant (Botha et al., 2017). These threats include unintentional poisoning (secondary poisoning during predator control attempts), intentional poisoning (for belief-based use or as part of sentinel poisoning), power line electrocutions, collisions with power infrastructure, food scarcity, habitat loss and degradation, disturbance from human activities, climate change, and other less prevalent threats such as drowning in farm reservoirs. Afterward, we pooled similar answers into categories or themes. For simplicity, only categories that were mentioned by more than one respondent are reported.

We expected differences in the perceptions (e.g., threats or benefits) of SFS between managers whose main income relates to livestock farming as compared to hunting activities. The financial capital of livestock farmers is directly influenced by the effects from carcasses (such as increased predator numbers or disease prevalence) either at SFS or on the farm in general, as they may influence livestock mortality rates. Farmers are thus required to manage carcasses to protect their livestock, but carcass management can be costly and labor intensive. SFS thus provides a relatively cheap and convenient method that SFS managers can exploit. People whose main income comes from hunting do not contend with these risks to the same extent and carcass management is thus less of a required management practice. Consequently, we thus expect them to have different attitudes towards SFS than livestock farmers. We predict that hunting operators would perceive more benefit from ecotourism and farmers more benefit from the cleaning services provided at SFS. We also predict that farmers will perceive more disadvantageous to running an SFS than hunting operators.

Based on responses from the questionnaire, we calculated two awareness scores for each SFS related to two different concepts. One was related to the number of population-level threats to vultures that managers could name, providing an estimate of manager knowledgeability on vulture conservation issues in a broad sense. The other was related to managers' awareness of two known food safety risks that can negatively impact vulture health and was thus directly related to potential risks experienced at individual SFS. The awareness scores for each concept were calculated as follows:

- 1 Broad knowledge of threats: We calculated the proportion of threats that a manager could name from those listed in the MSAP, thereby providing a score between zero and one (one being assigned when all threats, $n = 9$, in the MSAP were listed by the respondent).
- 2 Awareness of food safety risks: This was also calculated as a score from 0 to 1, where managers received 0.5 points for indicating that lead, and another 0.5 points for indicating veterinary drugs in carcasses could have a harmful effect on vultures (a score of 1 was thus given if they indicated both lead and veterinary drugs).

These two scores were then summed and divided by two to provide a score from 0 to 1, where 1 indicated full awareness of all threats to vultures (this term is hereafter "Awareness"). To spatially visualize these Awareness levels, we used inverse distance weighting interpolation (Santangeli, Arkumarev, Rust, & Girardello, 2016) on the Awareness score for each SFS based on its known coordinates and mapped the results. Inverse distance weighting assumes that each provided data point has a localized influence that diminishes with distance from that point. Using this assumption, this method then calculates scores for each spatial point for which there is no data, while giving greater weight to scores from data points closest to itself (Lu & Wong, 2008). The same approach was also recently used to interpolate poison use prevalence across Namibia (Craig et al., 2018; Santangeli, Arkumarev, et al., 2016). We used QGIS (2019) to construct this map.

2.1 | Statistical analysis

To evaluate whether there were differences in the perceived benefits, disadvantages, and awareness of each threat between SFS who generated income from livestock farming versus hunting, we used generalized linear models (GLM) with a binomial error structure and a logit-link function. Each identified benefit, disadvantage, and threat was modeled in isolation as a binary response variable (indicating whether it was mentioned by a manager or not) with SFS type (either livestock farming or hunting) as the predictor variable. The probabilities and 95% confidence intervals (CIs) were then calculated for each predictor using the estimated marginal means. These analyses were conducted using the *stats* and the *emmeans* package in the statistical software R (version 3.6.1) (Lenth, 2020; R Core Team, 2019). Some of the models did not run due to convergence problems caused by one or both categories in the predictor variable containing only zeros in the response data.

We explored the association between vulture visitation rate at SFS (obtained with the present survey) and

food provisioning rates at the same SFS (kilograms of meat or carcasses provided annually), obtained from Brink et al. (2020). For this analysis, we used a Pearson's product-moment correlation test.

3 | RESULTS

Of the 143 active SFS contacted, 114 (80%) participated in this survey. Although participation rate was high, not all respondents answered every question in the survey, resulting in varying sample sizes for each question. In most cases, categories were not mutually exclusive, and respondents often reported multiple categories. Over half of the questionnaires were conducted over the phone (61%) and the remainder via email (39%).

3.1 | Land management context in which SFS operate

Livestock farming was the most common main income-generating activity, reported by 50% of managers (Appendix S2). The second most common income-generating activity was tourism and hospitality, reported by 25% of managers, followed by hunting (20%) and game breeding (19%). These criteria were not mutually exclusive, and managers often reported multiple income sources. Viewing hides were present at 28% (of 105 respondents) of SFS (although 6% specified that these were for private use only).

3.2 | Perceived benefits and disadvantages

The cleaning service provided by vultures at SFS was mentioned by 44% of managers, making it the most widely perceived benefit (Figure 1). Despite this, few managers seemed to link this benefit to disease prevention, as this was only mentioned by 2% of managers (Figure 1). Thirty percent of managers also derived

personal pleasure or a feeling of satisfaction through running an SFS. Ecotourism was perceived as a benefit by 21% of managers. Some respondents (16%) perceived no benefits from the use of SFS. Less common benefits included facilitating research (7%) and the presence of vultures assisting in locating dead animals (2%). There appeared to be only a limited difference in the perceived benefits between SFS managers that were principally involved in livestock farming as compared with those involved in hunting. Ecotourism was the only perceived benefit that we analyzed, which differed between these two types of SFS sites (z value = -2.461 , $p = .01$, Appendix S3), with SFS managers on hunting farms being 6.8 times more likely to perceive ecotourism as a benefit compared to livestock farmers (Figure 2a, Appendix S3). Furthermore, locating mortalities was only mentioned by managers on hunting farms (5.3%, 95% CI = 0.7–29.4%) and disease prevention was only mentioned by managers

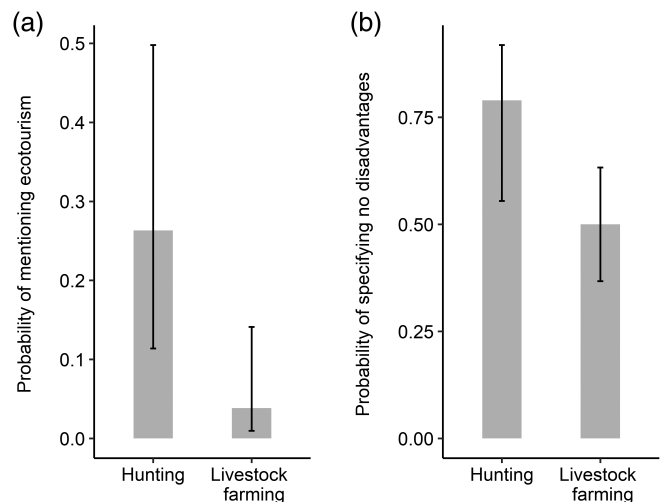
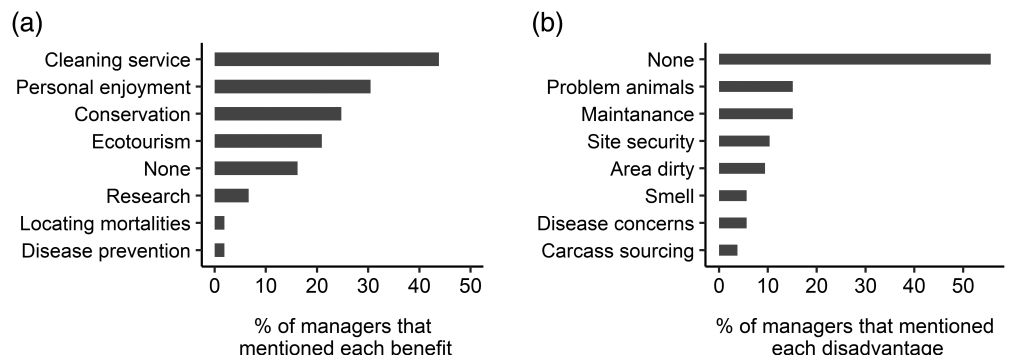


FIGURE 2 The probability that managers of differing supplementary feeding site types (livestock farming or hunting) would mention (a) ecotourism as a benefit of running a supplementary feeding site or (b) that there are no disadvantages to running a supplementary feeding site. Error bars indicate 95% confidence intervals

FIGURE 1 Benefits ($n = 105$, a) and disadvantages ($n = 106$, b) to having a supplementary feeding site as expressed by managers of active supplementary feeding sites in South Africa. Data were acquired via email and telephonic questionnaires. The categories in these graphs are not mutually exclusive



on livestock farms (1.9%, 95% CI = 0.3–12.4%, Appendix S3).

Over half of all managers (56%) reported no disadvantages to managing an SFS (Figure 1). The two most commonly identified disadvantages were increases in problem animals such as jackal (15%), and the effort in cleaning and maintaining the site (15%). Site security was the third most frequently expressed concern (10%, Figure 1), with some managers reporting increased trespassing on their properties caused by the SFS, which was also associated with carcass and infrastructure theft, as well as uncontrolled dumping at the site. The general “dirtiness” and “untidiness” of the site (9%), often related to the number of bones lying around, was also cited as a concern by some managers. Less common concerns included offensive smells emanating from SFS (6%), fears of disease spread (6%) with two managers stating that they fear their cows may become sick from chewing on bones (the most likely cause being botulism), and challenges concerning carcass sourcing (4%).

There were again little differences in the perceived disadvantages between SFS managers that were principally involved in livestock farming as compared with hunting SFS sites. Managers from hunting associated SFS were 1.6 times more likely to perceive no disadvantage from having an SFS when compared to livestock farmers (z value = 2.107, p = .035, Appendix S4; Figure 2b). Furthermore, increases in problem animals (19.2%, 95% CI = 10.7–32.2%) and carcass sourcing (3.9%, 95% CI = 1.0–14.1%) were disadvantages only mentioned by managers on livestock farms.

3.3 | Carcass sourcing

Over half of the managers (58%) provided carcasses exclusively from their own properties, 28% provided from their own and other properties, and 15% provided only carcasses originating from other properties. Of the carcasses that came from other properties, the vast majority (85%) were provided by neighboring farmers, followed by abattoirs and butcheries (22%). Other uncommon sources were veterinarians and the Society for the Prevention of Cruelty to Animals (animal welfare NGO) (3%), roadkill (2%), and police and security services confiscating stolen and poached animals (2%).

3.4 | Contamination risk mitigation

When asked about whether there were some carcasses that managers considered unsuitable to be provided at their SFS (Question 18, Appendix S1), the majority of

respondents (70%, of 103 respondents) indicated that there were some criteria with which they judged carcass suitability; the remaining 30% indicated that they provide all carcasses that become available. The presence of veterinary drugs in a carcass was the most common criteria by which SFS managers judged carcasses as unsuitable (Figure 3). Although managers commonly referred to veterinary drugs in general, some specifically mentioned drugs included nonsteroidal anti-inflammatories drugs, antibiotics, tranquilizers, and cortisone (Figure 3). Moreover, some managers avoided providing carcasses of animals dying from disease, preferring to dispose of such carcasses in a more direct manner (incineration or burying).

Only 10% of all managers mentioned that they actively avoided lead contamination in their carcasses. When considering only managers that provide game at their SFS (for which the issue of lead contamination will principally apply—i.e., from lead ammunition), 11% (of 38 respondents) indicated they avoided putting out lead-contaminated carcasses.

3.5 | Managers awareness of threats and unintended risks

When choosing the location for establishing the SFS, only 30% of SFS managers considered possible threats to vultures (Appendix S5). The most common criterion used when choosing a location, mentioned by 61% of managers, was the accessibility of the site to vultures (Appendices S5 and S6), followed by the accessibility of the SFS to farm staff, mentioned by 40% of managers. Some managers (19%) considered the ease of use of the sites for vultures when deciding on a location, which included having perching and roosting structures and having a water source close by. Most SFS (n = 65) did indeed have a water point nearby (40%) or at the SFS (32%), but 28% had no water point.

Respondents (n = 108) mentioned an average of three applicable threats (i.e., those identified by the MSAP; range: 0–9). The most commonly mentioned threats by managers were in order: power lines, belief-based use and unintentional poisoning (i.e., pertaining to secondary poisoning aimed at predator control; Figure 4). For testable threats, the awareness of each threat did not differ significantly between livestock and hunting associated SFS, but some threats were mentioned solely by managers on livestock farms, including food availability (15.4%, 95% CI = 7.9–27.9%), wind turbines (7.7%, 95% CI = 2.9–18.8%), human disturbance (3.9%, 95% CI = 1.0–14.1%), drowning (1.9%, 95% CI = 0.3–12.4%), and disease (1.9%, 95% CI = 0.3–12.4%) (Appendix S7). Vehicle

FIGURE 3 Carcass criteria that managers of active supplementary feeding sites in South Africa considered as unsuitable to provide to vultures ($n = 72$, a). Criteria related to veterinary drugs reported by managers who attempted to avoid providing veterinary drug contaminated carcasses at their feeding sites ($n = 61$, b). These are the constituents of the “Related to veterinary drugs” criteria in the figure to the left. None of the criteria in these graphs are mutually exclusive

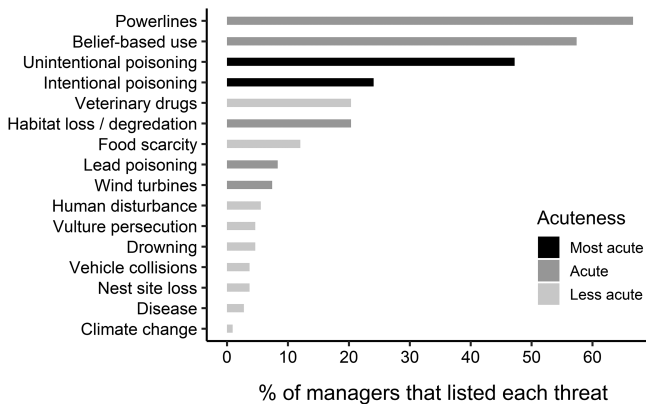
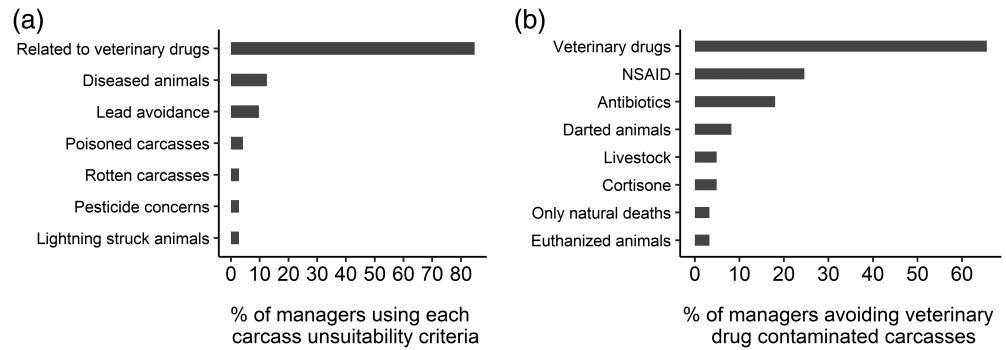


FIGURE 4 Percentage of supplementary feeding site managers ($n = 108$) who are aware of each threat listed by the Vulture MSAP. The relative acuteness of each threat in southern Africa (as specified by the MSAP) is indicated by the grey shading. MSAP, Multi-Species Action Plan

collisions (5.3%, 95% CI = 0.7–29.4%) were only mentioned by managers on hunting farms (Appendix S7). Awareness of threats showed a patchy spatial distribution, with hotspots of low awareness occurring along South Africa's northern border, Eastern KwaZulu Natal and throughout much of the Eastern Cape (Figure 5).

3.6 | Perceived population trends and vulture visitation at SFS

When asked about local vulture population changes of the last 10 years (Question 23, Appendix S1), managers ($n = 92$) were equally divided between those that believed numbers had increased (38%), were stable (33%), or had declined (27%), with a further 2% indicating that there was no discernible trend due to varying numbers.

The mean reported vulture visitation rate at SFS was 72 vultures per feeding event ($n = 98$, range: 0–300). There was a positive correlation between the average number of vultures visiting the SFS during feeding events and annual provisioning rate ($r = 0.398$, $t = 4.268$, $df = 97$, p value <.001, Appendix S8).

4 | DISCUSSION

Our results suggest that managers perceive various benefits from their SFS, while perceiving few disadvantages. We also identified a worrying lack of knowledge on best management practices meaning that some SFS may pose a risk to vultures. Several managers have low awareness of the main threats to vultures. As a result, often managers do not consider threats when choosing a location to place their SFS. Additionally, and perhaps of most concern, many SFS managers are not selective in the food they provide to the vultures, which may lead to vultures ingesting veterinary drugs or lead when feeding at SFS.

4.1 | Context in which SFS operate

The main income-generating activities (livestock farming, tourism and hospitality, hunting, game breeding, and crop farming) indicate that the vast majority of SFS are either being run from farmland or privately owned reserves. Livestock farming is intuitively the nexus around which SFS operate everywhere where they exist. For example in France, 95% of the 105 SFS are run by livestock farmers (Fluhr et al., 2017), while in Northern Spain, livestock farmers suggested food provisioning as the best way to conserve the Egyptian vulture population (Cortés-Avizanda, Martín-López, Ceballos, & Pereira, 2018).

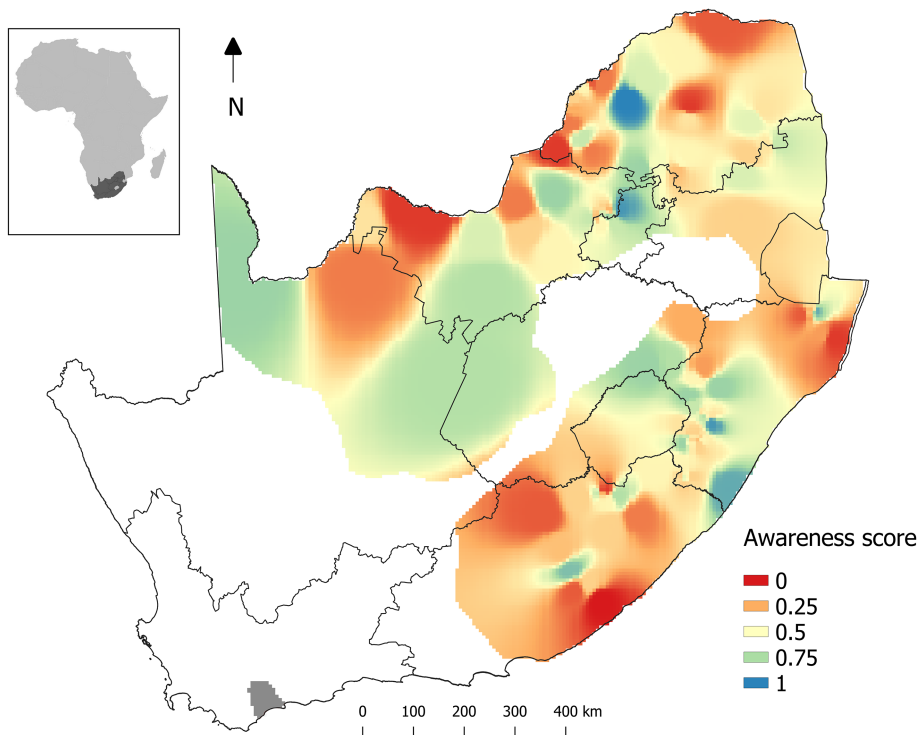


FIGURE 5 Awareness of supplementary feeding site managers of vulture threats and food safety concerns in South Africa, the colored and grey area indicates the cumulative distribution of six vulture species. The grey-shaded area contained only a single supplementary feeding site and these results were therefore excluded for anonymity reasons. The map was derived by using inverse distance weighting interpolation of calculated awareness scores (see Section 2) which were based on the number of relevant threats managers could list and whether they were aware of the risks of food contaminated with lead (Pb) and veterinary drugs to vultures. Higher scores indicate higher awareness

The context in which SFS operate can both influence how managers perceive risks to vultures associated with their SFS and determine what the best strategies for conservationists are to influence these perceptions. The majority of South African SFS are strictly for private use and do not provide carcasses sourced from other properties. Some managers expressed that this is because they want to maintain strict control of carcasses provided to vultures to ensure that the food is safe. If managers already foster such concerns then alleviating risks from contaminated carcasses, which our questionnaire suggests might be an issue, should be a simple case of ensuring that managers are well informed of which substances would be harmful to vultures. Unfortunately, most hunters in South Africa and elsewhere still ignore the threats that lead ammunition can pose to scavengers, and other wildlife (Cromie, Newth, & Reeves, 2015; Epps, 2014). This situation can be exacerbated by the reluctance of organizations trusted by the hunter community, to acknowledge the threats of lead ammunition to avian scavengers. For example, the South African Hunters and Game Conservation Association have an official stance that although they recognize the studies indicating increased blood lead levels in vultures, studies have in their opinion not sufficiently managed to link this to lead ammunition in carcasses (van de Geissen, 2019). Getting such organizations to promote best management practices and engaging properly with such stakeholders must be a priority if we are to ensure food placed at SFS is safe for vultures. Encouragingly, the

recently established South African Lead Task Team of the National Wildlife Poisoning Prevention Working Group includes several stakeholders from the South African hunting industry.

We found that most managers perceive at least some benefits from running an SFS. This suggests that most managers recognize and value some of the ecosystem services provided by vultures. These services fall mostly within a regulation and maintenance (related to carcass disposal) or cultural theme (related to the aesthetic and existence value of vultures) (Potschin & Haines-Young, 2011). The most widely perceived benefit was the cleaning service provided by vultures. This ecosystem service seems to be recognized elsewhere too (García-Alfonso et al., 2019; Morales-Reyes et al., 2018; Santangeli, Arkumarev, et al., 2016). In South Africa, other carcass disposal methods are burning or burying (personal observation) which is widely viewed as a good farm management practice, because carcasses are considered potential sources of diseases (e.g., botulism) which may cause stock losses (Radostits, Gay, Hinchcliff, & Constable, 2007). Carcass disposal can be a laborious and costly task, especially for intensive farming operations; therefore, using vultures is likely a more affordable and logistically feasible alternative. Most other perceived benefits fall under cultural ecosystem services, such as personal enjoyment in running an SFS. We can assume that managers that indicated that they receive no benefit from their SFS run them purely because they feel some sort of moral imperative to do so. Similarly, those managers that

highlight conservation or environmentalism as a benefit may run an SFS at least partly, for altruistic reasons, for example, for a sense of biophilia (Kellert & Wilson, 1993), and their participation in this activity may thus contribute to a sense of moral well-being.

Many of the perceived benefits and disadvantages of running SFS seem to correspond to the context in which they function. An understanding of how these contexts cause knowledge/attitude differences will enable conservation management to influence the managers of these sites. Managers from hunting SFS were for instance more likely to perceive ecotourism benefits from SFS. This may thus be a good avenue with which to influence such managers. Similarly, the most frequently mentioned disadvantage of SFS was that they cause an increase in problem animals such as predators that may attack livestock (e.g., black-backed jackals, *Canis mesomelas*). No manager of hunting SFS saw this as a disadvantage. Indeed, those managers seemed to be less affected by their SFS, with a higher proportion of them perceiving both no disadvantages as well as no benefits.

4.2 | SFS use and perceptions of vulture trends

Considering the current vulture declines experienced in Africa (Ogada et al., 2016), it is surprising that over a third of managers in South Africa perceived a local increase in vulture numbers at their SFS. This perception was also recorded in Namibia, where 68% of farmers perceive vultures to have increased on their farms during the previous 5 years (Santangeli, Arkumarev, et al., 2016). One explanation for the contrast in perception with known population trends may be the localized increase of vultures at sites after the initiation of an SFS. One manager, with a very high provisioning rate, explained that after a year of food provisioning without any vulture visits, they now observe between 100 and 300 vultures daily. This may explain why many managers assume, despite no scientific evidence, that their SFS are helping to increase vulture populations (personal observation). Increased activity at SFS may, however, not be an indicator of vulture population trends in the area, but rather the consequence of a shift in foraging activity towards SFS as opposed to other areas.

We found a correlation between number of vultures and the amount of food provisioned. This result may stem from vultures responding to the amount of food supplied at an SFS, or alternatively because the amount of food managers supply is reactionary to the numbers of vultures. If the former, it would suggest that vultures foraging behavior is being altered by SFS. Had vultures been

foraging naturally we would expect single feeding events to be drawing similar vulture numbers irrespective of the provisioning rate at SFS. If vultures are becoming dependent or habituated to this artificial food source, this may have important management implications (Fluhr et al., 2017). The latter might be less likely, since managers are likely to be restricted in their provisioning to their stocking and mortality rates, and thus only intensive farming operations will have the resources to respond to vulture numbers in any significant way. We therefore speculate that vultures responding to varying provisioning rates is a more likely hypothesis for the observed correlation.

4.3 | The potential costs to vultures from SFS

Species-centered conservation may have greater support when stakeholders better understand the value of the species in question. This can be achieved by highlighting the ecosystem services that vultures provide (Gangoso et al., 2013). The notion being that the species will be valued and protected in response.

With an average of 72 vultures visiting during each feeding event, and the ability to draw more than 300 vultures, SFS provide food for a considerable number of vultures. Indeed Brink et al. (2020) suggested that South African SFS may be fulfilling up to 83% of the total energy requirements of vultures in the region. This combined with the potential for dependency or habituation, means that SFS, if poorly managed, may have considerable population-level effects on vultures in the region, through luring vultures into areas with increased risk of mortality and exposure to unsafe food.

Many SFS managers do not have good awareness about the threats currently facing vultures, with managers on average only being able to name about three of the nine applicable threats (as identified by the MSAPs). Threat knowledge also did not correspond well to the importance of the threat in the region. Poisoning, for instance, is widely recognized as the main threat to vultures. On farms, this specifically relates to the use of poisons for predator control. More than half of managers seem to be unaware that this behavior threatens vultures, or perhaps they do not believe that it commonly occurs. Some managers indicated that they use poison to target predators, however, they believe they do so in a way that removes any risk to vultures (e.g., using small parcels of poisoned bait). In Namibia, 88% of interviewed commercial farmers indicated that they used poisoned baits in a similar way and 12% indicated that they poisoned larger carcasses (Santangeli, Arkumarev, et al., 2016). If

poison-use rates in South Africa are comparable to those in Namibia, this would pose a severe hurdle to ensuring that vultures persist in the country. Worryingly, increases in problem animals (referring to predators) was the most cited disadvantage of SFS. This was already shown in previous studies (Yarnell, Phipps, Dell, MacTavish, & Scott, 2015). Consequently, SFS may cause increased predator numbers, leading to higher stock losses and increased likelihood of managers or neighboring farmers to use poison. In this way SFS may exacerbate human-wildlife conflict.

Other safety concerns relate to the food provided at SFS themselves. Previous studies show that few SFS managers consider lead to be harmful to vultures (Brink et al., 2020). This will, however, mostly be a concern at the 38% of SFS that provide hunted game carcasses (Brink et al., 2020). Surprisingly when we asked these game providing managers what criteria they use to screen carcasses for provisioning, only 11% mentioned lead avoidance (Question 18, Appendix S1). When asked directly whether they believed lead could have detrimental health effects on vultures, however, 41% of these managers agreed that lead could have detrimental effects on vulture health (Question 30, Appendix S1; Brink et al., 2020). It thus seems that although some managers know that lead is harmful to vultures, they do not necessarily translate this knowledge into actions to minimize risks from lead contamination. Vultures are likely exposed to lead at SFS. A recent study showed how widespread lead exposure was for vultures in South Africa (van den Heever et al., 2019). Contamination at SFS may contribute to the above mentioned results and explain why lead levels in South Africa are so much higher than for other regional populations (Garbett et al., 2018 compared to van den Heever et al., 2019). Moreover, it is still common for statutory conservation agencies to provide animals from culling operations or animals that were poached, which also likely contain lead, for vultures to feed on.

SFS managers recognize the potential toxicity of veterinary drugs to vultures (Brink et al., 2020) and this is the most widespread consideration in terms of determining if carcasses are suitable to be fed to vultures. However, 28% of SFS managers remain unaware of the potential negative effects of veterinary drugs (Brink et al., 2020). It is also worrisome that some SFS provide carcasses originating from the Society for the Prevention of Cruelty to Animals and veterinarians who routinely euthanize animals. Despite most SFS managers being aware of the immediate threat of veterinary drugs to vulture health (Brink et al., 2020), few considered it to be a real threat to vultures in a more general sense. It is also important to note that sentiments about which drugs are

safe for vultures and which are not may differ widely. The risks associated with veterinary drugs may be ameliorated by the influence of veterinarian professionals, one respondent, for instance, specified that although they provide all carcasses that become available, they have switched some of their medicines to those that their veterinarian advised is safe for vultures. This could be true for other SFS as well.

SFS managers recognized the threat of power lines to vultures, but only a few managers indicated that they considered the proximity to power lines when selecting a location for their SFS. It might be that many managers just did not need to consider this as power lines were not present in their candidate areas. Some SFS, however, do occur near power lines despite managers being aware of power line associated vulture mortalities at these sites (personal observation).

SFS may also be easy targets for criminals aiming to harvest vultures for the belief-based use market (Mateo-Tomás & López-Bao, 2020; McKean et al., 2018). One SFS manager divulged that they had once discovered a sack full of vulture parts on the side of the road next to their property. Another had apprehended persons with a live and injured vulture. Such incidences may become more common as it has been suggested that the current rise in sentinel poisoning may stimulate the illegal trade in vulture parts (Mateo-Tomás & López-Bao, 2020).

Currently, SFS are unregulated and left to the discretion of single private individuals. We show that some of these individuals are unaware of the risks their management decisions pose to vultures and many do not conform to best management practices. This should be urgently addressed to avoid a situation where SFS cause issues for vultures and it is the role of the scientific community to deliver the knowledge and tools necessary to ensure sustainable use of such ecosystem services. This could either be done through increasing educational awareness and training from the conservation NGOs that are involved with several of these sites, or if this measure fails, government regulation of SFS.

5 | CONCLUSIONS

In South Africa, SFS mostly operate within a farming context and the free cleaning service provided by vultures is a widely valued benefit. SFS managers seem to experience minimal disadvantages in running such operations. Although SFS may have beneficial effects on vulture populations some costs need to be considered as well. Many such costs will stem from the fact that SFS managers seem to have a low awareness of the threats vultures may face and how their feeding sites may

contribute to this risk, especially with regards to food safety. We suggest increased interaction and communication between conservation practitioners and SFS managers. Such efforts may be particularly urgent in those areas we have identified as associated with low SFS manager awareness of vulture threats and the food contamination risks, particularly in the northeastern region of South Africa, which also represents a global priority for vulture conservation (Santangeli et al., 2019).

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

Christiaan W. Brink, Andrea Santangeli, Arjun Amar, and Robert L. Thomson conceived the idea and designed the study. Kerri Wolter, Gareth Tate, Sonja Krüger, and Andrew S. Tucker procured contact information for respondents and facilitated contact. Data collection, preparation, and analysis were conducted by Christiaan W. Brink with input from Andrea Santangeli, Arjun Amar, and Robert L. Thomson. The manuscript was written by Christiaan W. Brink, Andrea Santangeli, Arjun Amar, and Robert L. Thomson. All authors reviewed drafts of the paper.

DATA AVAILABILITY STATEMENT

Due to interview confidentiality, data are not made available online. However, anonymous data can be requested, with motivation, from authors via email.

ETHICS STATEMENT

This study was approved by the Faculty of Science Research Ethics Committee at the University of Cape Town (Approval code: FSREC 83–2017) and participants provided informed verbal consent for participation.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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